Author Manuscript
Author Manuscript
Author Manuscript

Published in final edited form as:
Min Metall Explor. 2019 December ; 36(6): 1137–1144. doi:10.1007/s42461-019-0077-3.

Overview of Current US Longwall Gateroad Support Practices: an Update

M. M. Sears[1], **G. S. Esterhuizen**[1], **I. B. Tulu**[2]

[1]National Institute for Occupational Safety and Health, 626 Cochrans Mill Rd, Pittsburgh, PA, USA

[2]West Virginia University, Morgantown, WV 26506, USA

Abstract

In 2015, 40 longwall mines provided nearly 60% of the US coal production from underground mining methods. This represents a substantial yet gradual increase from just under 50% over the last 5 years. As a result of this increased production share, the percentage of ground-fall-related fatalities in longwall mines has also increased when compared to all US underground coal mines. Additionally, about 80% of ground-fall-related fatalities have occurred in areas where the roof was supported. In an attempt to better understand the status quo of current US longwall support practices, a sample of 25 longwall mines were visited representing nearly 50% of the currently active longwall mines representing all of the major US longwall-producing regions. The resulting data was obtained from a wide variety of overburden depths, geologic conditions, mining heights, ground conditions, support practices, and gateroad configurations. The data collected is reported using both qualitative and quantitative methods. Results from the research update previous efforts in classifying mining accidents and injuries as well as current support practices presented by this author at the 2017 Society for Mining, Metallurgy, & Exploration Annual Meeting. This data provides a necessary background for future research aimed at further reduction of ground fall accidents and injuries.

Keywords

Longwall; Coal; Mining; Roof support; Gateroad; Standing support

1 Introduction

Maintaining ground stability in gateroad entries is essential for longwall productivity and safety [4]. In 2015, 148 reportable roof falls occurred in US longwall mines. About 34% of these resulted in mineworker injuries. Safety considerations not only include injury from roof and rib falls but also egress from the longwall face during an emergency [11]. Over the past 30 years, a number of researchers have studied longwall tailgate support performance [8]. This research aims to take a snapshot of the ground support installed in modern US

* M. M. Sears, msears@cdc.gov.

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

longwall mines and provide a supplement and update to the overview provided by Barczak [2]. This will provide a framework for future research into improving gateroad support systems.

2 Background

Large unplanned roof falls at or above the primary support or those impeding travel and/or ventilation must be reported to the Mine Safety and Health Administration (MSHA). Reportable roof falls, normalized based on production in million metric tons, generally relate to the amount of roof exposed during the mining process [13] and provide an evidence-based statistical background for this review of current support practices. Figure 1 shows the reportable roof fall rate in US underground longwall mines for the period 2006–2015 [10].

Over the past decade, roof fall rates have shown a gradual decrease with numbers now at a rate nearly half of what was observed just 5 years ago. However, over the past few years, roof fall rates in US longwall mines appear to have stagnated at levels just over 1 per 2,000,000 tonnes mined.

Similarly, roof fall injury rates in the nation's longwall mines have also seen a reduction over the past decade. Figure 2 shows the roof fall injury rate in US longwall mines per 200,000 employee hours.

Statistics such as these, as useful as they are, do not differentiate between roof falls that occur near the longwall face as a direct result of longwall mining operations and those that occur outby, on development sections, or in other locations such as the bleeder entries. To better understand the rates at which falls are occurring in the gateroads during longwall retreat, an additional layer of investigation is required. The MSHA accident and injury database provides a brief narrative of the event that occurred. In the majority of cases, a researcher can determine if a fall has occurred in the headgate, tailgate, or other area of the mine with a bit a diligence. In total, narratives from 214 non-injury reportable roof falls were examined. Figure 3 presents the rate of roof falls causing a head-gate or tailgate blockage, preventing egress off the longwall face, or other roof fall that did not impede the travel of miners that was known to exist near areas where miners could be expected to be working near the longwall face.

It should be noted that narratives within the MSHA accident and injury database can be subjective and sometimes ambiguous. For example, in this time frame, seven roof fall events were unable to be classified. This leads one to assume that there could be some roof fall events that were missed or misclassified because it was not explicitly stated where these falls occurred. Therefore, one should read the previous data as a minimum rate of longwall roof falls that occurred in a given year. Additionally, these do not include areas of longwall setup, recovery, or cut-through of open entries which are well documented in other research [3, 6, 7, 9, 12, 14, 15].

The roof fall rates occurring near the longwall face have seen similar declining trends over the past decade, particularly in the category of tailgate blockages. One of the reasons for this trend is most likely due to increased awareness of post-disaster escape after a string of mine fires and explosions during the first half of the decade. Of particular interest is the rate of roof falls near the longwall face compared with all longwall mine roof falls. Assuming that unclassified roof falls are negligible, only about 12% of roof falls occur in the area of the working longwall. This implies that the majority of roof falls occur in other locations such as development sections or outby areas. Nevertheless, the preceding accident and injury statistics provide a quantitative basis for the discussion on longwall ground support installed in US longwall mines over the past few years.

2.1 Gateroad Database

2.1.1 Site Visits—Over the past 5 years, case histories were collected by NIOSH researchers from 25 mines resulting in a total of 34 cases. Seventeen of these cases were collected over the past 2 years as part of a renewed gateroad ground control research effort. These cases represent a broad range of mining environments including operations in ten states extracting coal from all of the major US longwall producing basins.

2.1.2 Panel Layout—The mines surveyed for this research effort represent a broad range of geologic and depositional environments. Additionally, parameters associated with the loading conditions experienced at the mines varied from site to site. Summary statistics for the overburden depth, mining height, entry widths, and the number of gateroad entries can be found in Table 1.

Mine geometry varied considerably from one operation to the next. Two of the observed mines utilized a two-entry yield pillar configuration. In these mines, gateroad pillar widths were about 14.6 m (48 ft.) C–C and the mining height was approximately 2.4 m (8 ft.). Additionally, one of these mines utilized an inter-panel barrier layout when the depth of cover approached 900 m (3000 ft.) with a barrier width of about 145 m (480 ft.)

Two other observed mines used a four-entry yield-abutment-yield configuration. These mines employed yield pillar widths of 13.7 m and 15.2 m (45 and 50 ft.) C–C, respectively. Associated abutment pillar widths of 42.7 m and 51.8 m (140 and 170 ft.) C–C were observed. In these cases, the mining height was approximately 2.1 to 2.3 m (7 to7.5 ft.).

The remaining mines used three-entry systems with observed pillar widths ranging from 15.2 m to 39.6 m (50 to 130 ft.) C–C with an average width of 28.2 m (92.6 ft.). While some of these mines used equal-sized pillars, most employed a smaller (yield) pillar and a larger (abutment) pillar even though these pillars are not designed to yield in the traditional sense. The average mining height for the three-entry cases was 2.6 m (8.5 ft.)

Crosscut spacing at all observed mines ranged from 30.5 m (100 ft.) to 137.2 m (450 ft.) C–C, with crosscuts developed on the smaller (yield) block being spaced at one-half or one-third intervals when crosscut spacing exceeded 200 ft. for the larger (abutment) pillar. Table 2 details the panel geometry for the observed mines including width of the gateroad (excluding inter-panel barrier), panel width, panel length, and mouth of panel barrier width. Some of these values were not available for all cases where n denotes the number of observations.

2.1.3 Headgate Support—This section focuses on the installed support in the longwall headgate entry. Because this entry contains the stageloader and belt structure, the ability to add standing support is limited. Additionally, in some mines, the amount of roof support installed in the headgate varied from that installed in the tailgate and other areas of the mine. Of the 34 case histories in the database, 23 of those contained at least some information on the primary support in the headgate. This information is listed in Table 3 along with the calculated reinforcement density index for 20 of the cases [9].

Secondary support in the headgate typically consisted of cable bolts installed on cycle. In some cases, cable or rigid trusses were also installed either as secondary or supplemental support. Standing support was typically limited to roadway posts installed along the rib on the walkway side of the belt to afford additional roof and rib fall protection to miners working or traveling in that area. Overall, based on discussion with mine personnel, secondary and supplemental support were installed based on successes and failures observed in other areas of the mine and tended to be installed more often and in higher densities in areas of poor roof conditions and or elevated stress conditions. Four cases in the database did not regularly use secondary support in the observed areas. Summary statistics for cases where cable bolts and/or trusses were installed as secondary support can be found in Table 4.

2.1.4 Tailgate Support—Tailgate support, for the purposes of this paper, typically means the standing or cable/truss support systems installed in the tailgate and #2 entries of the gateroad system prior to longwall mining. Most longwall mines have several, if not all, major types of standing support available to them. This research focuses on the standing supports actually installed during observation or in discussion with the mine.

The types of standing supports observed within the database have been lumped into six major categories regardless of manufacturer: wood cribs, engineered wood cribs, can-type supports, pumpable cribs, and yielding posts (see Figs. 4, 5, 6).

Most mines utilized a single support type and varied the support density depending on mining height, depth of cover, geologic conditions, etc. However, three mines (13%) routinely used more than one type of support in a given panel as a routine part of the design. Other mines reported either frequent use of a second support system or routinely using what system was available at the time. Two mines had the option to use “cribless” tailgates when mining under a certain depth of cover. Figure 7 shows the distribution of observed mines utilizing a given support system. For example, 46% of observed mines were using can type supports. If one of those mines also used pumpable cribs, that mine is also included in the 38% of mines using that support system. This does not include support systems installed in setup and recovery rooms, which are wider than typical gateroad entries and typically require much higher levels of ground support.

Over the past 5 years—the time frame considered within the database—the number of longwall mines in the US decreased from 48 to 40. This number stands to decrease again this year. The implications of this are that six mines within the database are no longer operational. If one considers only the active mines remaining in the database, the distribution of support type does change (Fig. 8). Of the remaining 18 observed mines, can-type supports and traditional wood cribs both saw a decrease in prevalence.

In order to quantitatively classify these support systems, support load bearing capacity was determined from those used in the Support Technology Optimization Program (STOP) or from manufacturer's specifications [1]. All of these types of support systems have been or are being tested at the NIOSH Pittsburgh Mining Research Division Mine Roof Simulator (MRS). Table 5 shows the summary statistics for standing and/or cable support in the tailgate and #2 entry, detailing the number of rows of support and the calculated standing support density or SSD [9].

Prior to recent mine disasters, particularly the Upper Big Branch explosion, little to no emphasis was placed on secondary and/or standing support in the #2 entry [8]. This is reflected in the number of cases in the database where the type and amount of support in the #2 entry are quantified. Most likely, more than just one of these cases employed no standing support in this entry at all. However, discrimination between the number of cases with no support and the number of cases where the installed support was simply not emphasized is not available. As with all the data presented in this paper, this should be considered as the range of installed support within the bounds of the known observed cases. From a ground fall safety perspective, the support installed in the tailgate entry is more valuable in terms of protecting mine workers in areas where they are likely to be located and/or traveling.

2.1.5 Observed Ground Conditions—Ground conditions including the roof, rib, and floor from a stress and geologic perspective were recorded and mapped to the extent possible given the constraints afforded by the operator. As expected, overall conditions ranged from poor to very good. However, conditions in the area traveled represent only a snapshot of what has been experienced by the mine in recent history. This causes a skew in the data toward the average-very good end of the conditions scale. This skew is not unexpected because even the mines that experience the highest rate of reportable roof falls have support systems that are considered to be 98 + % effective [5]. Therefore, the accident and injury rates discussed previously provide an arguably better metric of support effectiveness than single site visits alone.

3 Conclusions

This paper has presented an overview of recent trends in US longwall mining. Emphasis was placed on accident and injury trends as well as data collected by a number of NIOSH researchers detailing support systems and observed ground conditions across the country. The data was then organized and provided in the form both qualitative and quantitative summaries.

The data presented implies that the types and amount of support being installed in modern US longwall mines have reduced ground fall accident and injury rates to levels which have never been seen before. However, the complete elimination of unintended roof falls in US longwall mines has remained elusive. This data can be used by mine operators and engineers to determine where their chosen type and density of support falls on the spectrum of observations contained in this database. Additionally, this data can be used to enhance, supplement, and support additional research on longwall gateroad support systems.

Funding information

This study received financial support from the National Institute for Occupational Safety and Health.

References

1. Barczak TM (2000) Optimizing secondary roof support with the NIOSH support technology optimization program (STOP). In: Proceedings of the 19th International Conference on Ground Control in Mining, 7, pp 77–83
2. Barczak T (2005) An overview of standing roof support practices and developments in the United States. In: Proceedings of the Third South African Rock Engineering Symposium: South African Institute of Mining and Metallurgy, Johannesburg, Republic of South Africa, 10, pp 301–334
3. Barczak T, Tadolini S, Zhang P (2007) Evaluation of support and ground response as longwall face advances into and widens pre-driven recovery room. In: Proceedings of the 26th International Conference on Ground Control in Mining, 8, pp 160–172
4. Campoli AA (2015) Selection of pumpable cribs for longwall gate and bleeder entries. In: Proceedings of the 34th International Conference on Ground Control in Mining, 7, pp 80–82
5. Esterhuizen GS (2012) A stability factor for supported mine entries based on numerical model analysis. In: Proceedings of the 31st International Conference on Ground Control in Mining, 7, pp 1–9
6. Gearhart DF, Jones TH, Compton CS, Minoski TA, Ochsner RE (2014) Ground response as a longwall advances into a backfilled recovery under low cover. In: Proceedings of the 33rd International Conference on Ground Control in Mining, 7, pp 1–10
7. Heasley K, Worley P, Zhang Y (2003) Stress analysis and support design for longwall mine-through entries (a case study). In: Proceedings of the 22nd International Conference on Ground Control in Mining, 7, pp 11–18
8. Mirabile B (2015) Numerical modeling of standing support performance in entries between longwall gobs. In: Proceedings of the 34th International Conference on Ground Control in Mining, 7, pp 359–362
9. Mirabile B, Poland JR (2016) Safe, efficient, and cost-effective support of longwall cut-through entries. In: Proceedings of the 35th International Conference on Ground Control in Mining, 7, pp 83–89
10. MSHA (2016) Accident, illness and injury and employment self-extracting files (part 50 data), 2006–2016. http://arlweb.msha.gov/stats/part50/p50y2k/eatable.htm. Accessed June 2016
11. Mucho TP, Barczak TM, Dolinar DR, Bower J, Bryja JJ (1999) Design methodology for standing secondary roof support in longwall tailgates. In: Proceedings of the 18th International Conference on Ground Control in Mining, 7, pp 136–148
12. Oyler D, Frith R, Dolinar D, Mark C (1998) International experience with longwall mining into pre-driven rooms. In: Proceedings of the 17th International Conference on Ground Control in Mining, 7, pp 44–53
13. Pappas DM, Mark C (2012) Roof and rib fall incident trends: a 10-year profile In: Transactions of the Society of Mining Metallurgy and Exploration, Inc., 330 Englewood, CO, pp 462–478
14. Seymour B, Tesarik D, Larson M (1998) Stability of backfilled cross-panel entries during longwall mining. In: Proceedings of the 17th International Conference on Ground Control in Mining, 7, pp 11–20
15. Thomas R (2008) Recent developments in pre-driven recovery road design. In: Proceedings of the 27th International Conference on Ground Control in Mining, 7, pp 197–205

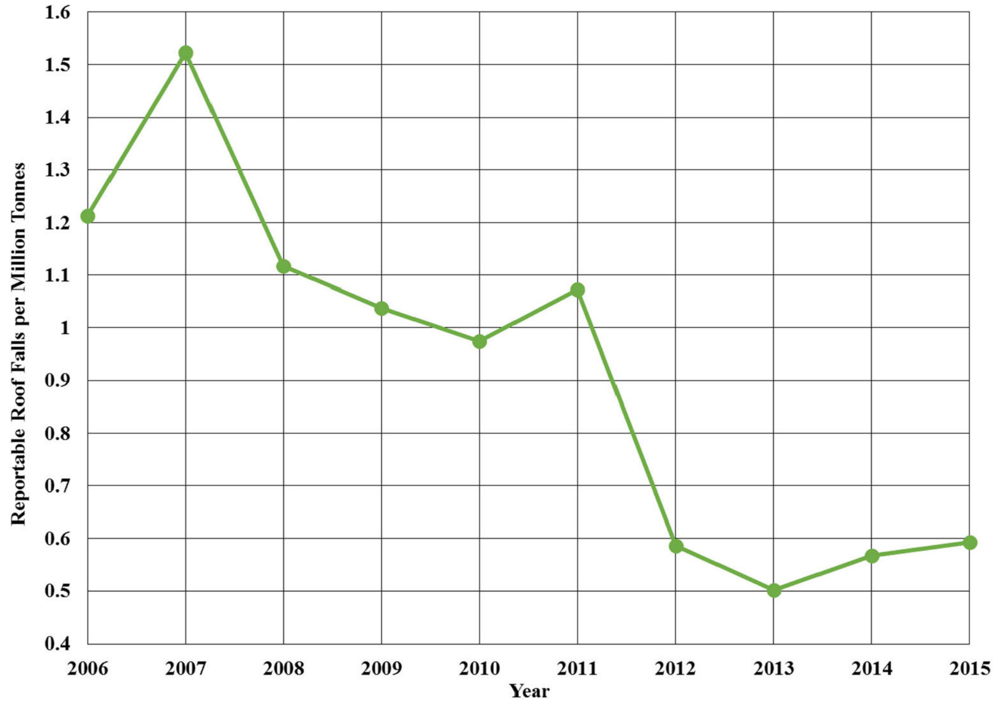

Fig. 1.
Reportable roof fall rates in US longwall mines

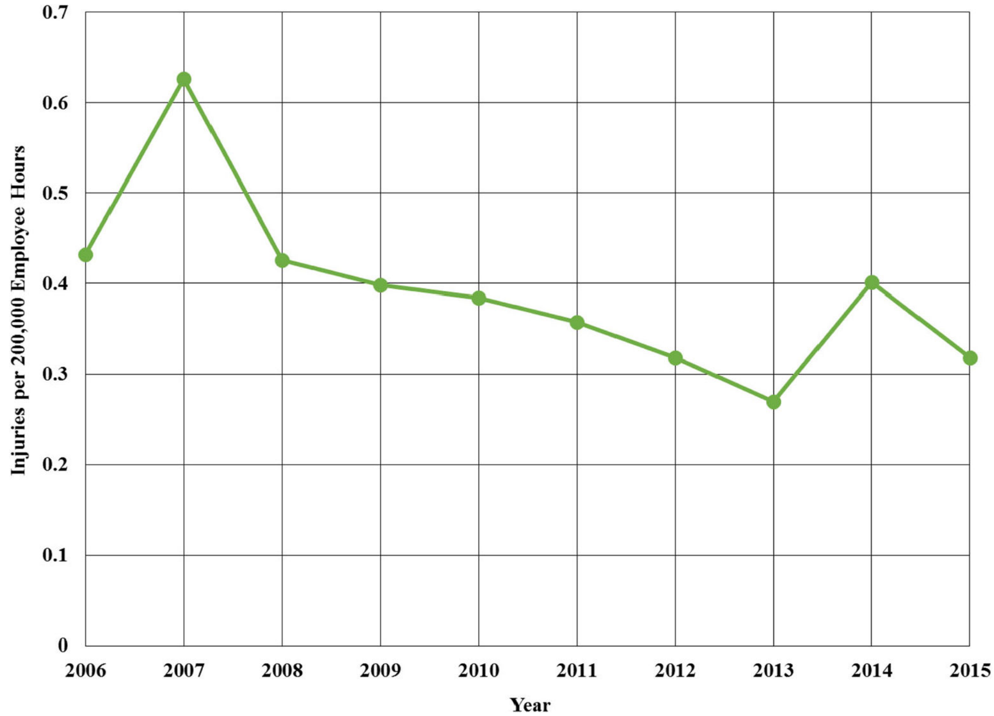

Fig. 2.
Reportable injury rates in US longwall mines

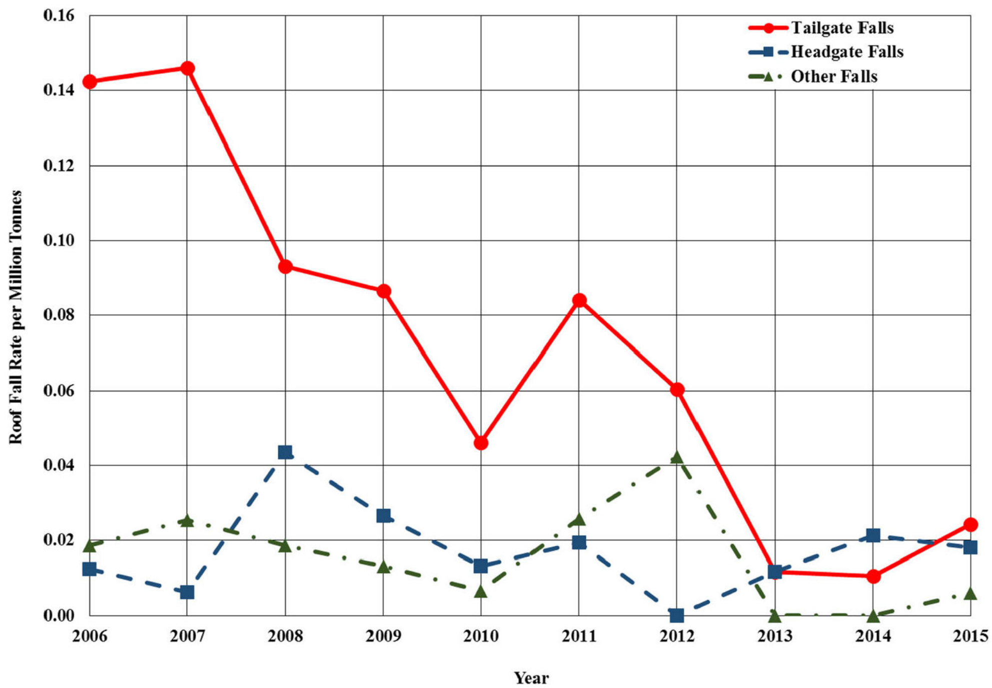

Fig. 3.

Roof falls rates that resulted in a gateroad blockage or other nearby fall

Fig. 4.
Example of a four-point crib (left) and an engineered wood crib (right)

Fig. 5.
Example of a can type support (left) and pumpable crib (right)

Fig. 6.
Example of yielding post (left) and cluster of three yielding posts (right)

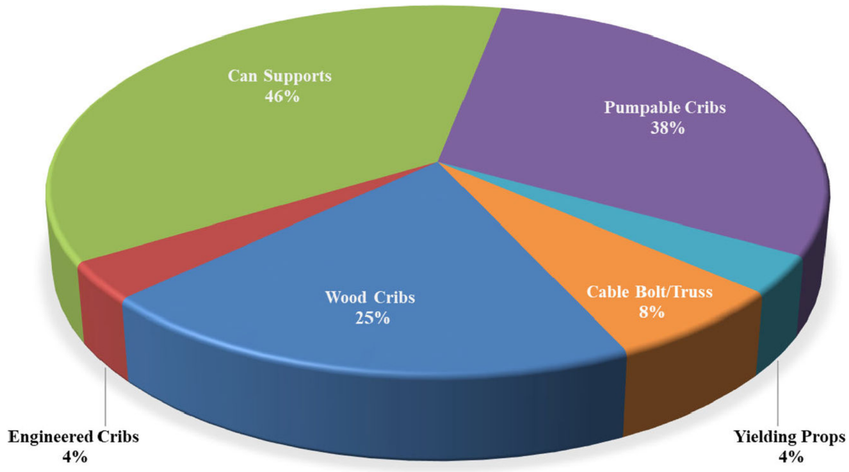

Fig. 7.
Percentage of observed longwall mines utilizing a given support type

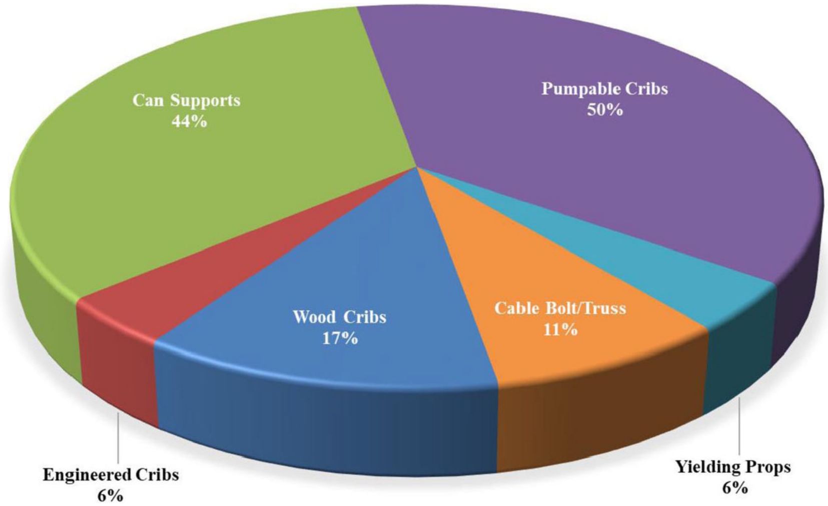

Fig. 8.

Percentage of active longwall mines (2016) utilizing a given support type. Can-type support diameters ranged from 45.7 cm (18 in.) to 91.4 cm (36 in.) with the majority of those being of the 45.7 cm (18 in.) or 61 cm (24 in.) variety. Pumpable support diameters were either 61 cm (24 in.) or 76.2 cm (30 in.). The design and selection of these diameters depends on support capacity needs, the amount of roof coverage desired, and most importantly the aspect ratio of the support. For can type supports, the aspect ratio should be kept at five or less while the aspect ratio for pumpable cribs should be a maximum of four. Mines using yielding props typically turned to wooden cribs to provide the necessary aspect ratio in scenarios where the mining heights exceeded 3 m (10 ft.).

Table 1

Summary statistics for general mine data

	Min	Mean	Max
Depth	122 m (400 ft.)	374 m (1228 ft.)	915 m (3000 ft.)
Mining height	1.8 m (6 ft.)	2.7 m (8.8 ft.)	3.7 m (12 ft.)
Entry width	4.9 m (16 ft.)	5.7 m (18.7 ft.)	6.7 m (22 ft.)
# Entries	2	3	4

Table 2

Summary statistics for panel layout

	Min	Mean	Max	*n*
Gateroad width (C-C)	14.6 m (48 ft.)	55.0 m (180 ft.)	82.3 m (270 ft.)	27
Panel width	182.9 m (600 ft.)	315.7 m (1036 ft.)	457.3 m (1500 ft.)	26
Panel length	1524 m (5000 ft.)	3096 m (10,156 ft.)	6707 m (22,000 ft.)	18
Barrier width	67.1 m (220 ft.)	130.8 m (429 ft.)	228.7 m (750 ft.)	20

Table 3

Summary statistics for headgate primary support

	Min	Mean	Max	*n*
Length	1.5 m (5 ft.)	1.9 m (6.1 ft.)	2.7 m (9 ft.)	23
Diameter	#6	#7	#8	20
#/Row	2	4.9	6	21
Row spacing	1.2 m (4 ft.)	1.4 m (4.6 ft)	1.5 m (5 ft.)	22
RDI	0.12 MPa-m (57 psi-ft)	0.18 MPa-m (84.4 psi-ft)	0.27 MPa-m (129.5 psi-ft)	20

Table 4

Summary statistics for headgate secondary support (cable bolts/trusses)

	Min	Mean	Max	*n*
Length	2.4 m (8 ft.)	3.4 m (11 ft.)	4.9 m (16 ft.)	11
Diameter	1.5 cm (0.6 in.)	NA	1.8 cm (0.7 in.)	11
#/Row	1	2.3	4	11
Row spacing	1.2 m (4 ft.)	1.9 m (6.4 ft.)	3 m (10 ft.)	11
RDI	0.11 Mpa-m (54 psi-ft.)	0.22 Mpa-m (103 psi-ft)	0.43 Mpa-m (205 psi-ft)	11
Combined RDI	0.23 Mpa-m (111 psi-ft)	0.41 Mpa-m (193 psi-ft)	0.70 Mpa-m (333 psi-ft)	11

Author Manuscript

Author Manuscript

Author Manuscript

Table 5

Summary statistics for tailgate standing/cable support

	Min	Mean	Max	*n*
# / Row in tailgate	1	1.9	3	31
# / Row in #2 entry	0	1.5	2	13
SSD in tailgate	0.03 Mpa (4.2 psi)	0.10 Mpa (14.2 psi)	0.23 Mpa (33.8 psi)	31
SSD in #2 entry	0.00 Mpa (0.0 psi)	0.07 Mpa (10.4 psi)	0.19 Mpa (28.1 psi)	13